Science of the Total Environment 636 (2018) 597–609

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Assessing changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria

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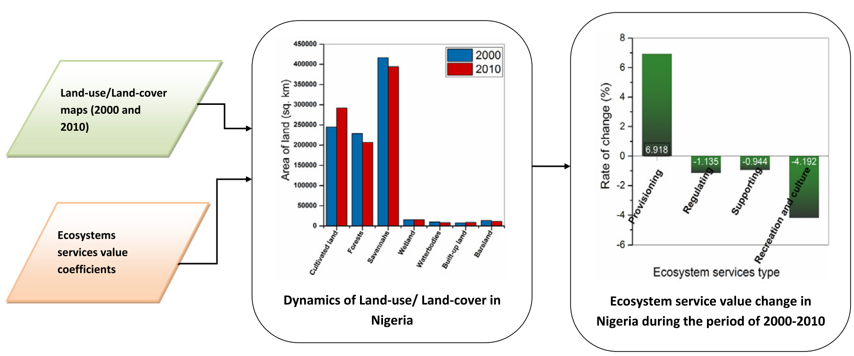
HIGHLIGHTS

- Land-use/land-cover (LULC) patterns are changing fast in Nigeria.
- We examined the impact of LULC dynamics on ecosystem services value (ESV).
- Cultivated land sprawl over forests and savannahs was predominant from 2000 to 2010.
- We estimate 4.83% decline in total ESV of the natural ecosystems during 2000–2010.
- About 70% of the ecosystem service functions have been degraded in Nigeria.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 26 February 2018
Received in revised form 16 April 2018
Accepted 20 April 2018
Available online 30 April 2018

Editor: Jay Gan

Keywords:
Forests
Savannah
Agricultural expansion
Value coefficients
Benefits transfer

ABSTRACT

Increasing human activities worldwide have significantly altered the natural ecosystems and consequently, the services they provide. This is no exception in Nigeria, where land-use/land-cover has undergone a series of dramatic changes over the years mainly due to the ever-growing large population. However, estimating the impact of such changes on a wide range of ecosystem services is seldom attempted. Thus, on the basis of GlobeLand30 land-cover maps for 2000 and 2010 and using the value transfer methodology, we evaluated changes in the value of ecosystem services in response to land-use/land-cover dynamics in Nigeria. The results showed that over the 10-year period, cultivated land sprawl over the forests and savannahs was predominant, and occurred mainly in the northern region of the country. During this period, we calculated an increase in the total ecosystem services value (ESV) in Nigeria from 665.93 billion (2007 US$) in 2000 to 667.44 billion (2007 US$) in 2010, 97.38% of which was contributed by cultivated land. The value of provisioning services increased while regulation, support, recreation and culture services decreased, amongst which, water regulation (−11.01%), gas regulation (−7.13%), cultural (−4.84%) and climate regulation (−4.3%) ecosystem functions are estimated as the most impacted. The increase in the total ESV in Nigeria associated with the huge increase in ecosystem services due to cultivated land expansion may make land-use changes (i.e. the ever-increasing agricultural expansion in Nigeria) appear economically profitable. However, continuous loss of services such as climate and water regulation that are largely provided by the natural ecosystems can result in huge economic losses that may exceed the apparent gains from cultivated land development. Therefore, we advocate that the conservation of the natural

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https://doi.org/10.1016/j.scitotenv.2018.04.277
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ecosystem should be a priority in future land-use management in Nigeria, a country highly vulnerable to climate change and incessantly impacted by natural disasters such as flooding.

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1. Introduction

Ecosystems through their functioning provide a multitude of services, which are essential for human survival, livelihoods and well-being (Costanza et al., 1997; MEA, 2005). These range from provisioning (e.g. food, water and fuel), regulating (e.g. climate regulation and water purification) and cultural services (e.g. recreation and aesthetic values) that directly affect people to supporting services (e.g. soil formation and erosion control) with a relatively indirect impact on people (MEA, 2005; de Groot et al., 2010). However, the provision of these services has been greatly altered by land-use/land-cover (LULC) dynamics. Even though alteration of the land by humankind to obtain food, fiber, fuel and other necessities has been ongoing for millennia, the pace, extent and intensity of change these days have accelerated sharply than were in the past (Ellis and Pontius, 2007) and only a few landscapes on the face of the planet remain relatively undisturbed (Sanderson et al., 2002; Zubair, 2006; Giri, 2012).

Due to the expanding human population, economic development and urban sprawl, LULC have experienced enormous changes throughout the world during the last decades particularly from forests, savannahs and other native landscapes to croplands, pasturelands and built-up areas (Vitousek et al., 1997; Lambin and Meyfroidt, 2011; Chen et al., 2014). Robertson and Swinton (2005) estimated global expansion of agricultural lands mainly from forests at about 13 million ha/yr and presently close to 40% of the earth's surface area is being cropped or grazed (Foley et al., 2005). LULC changes from the natural ecosystems have impacted biotic diversity and undermined their capacity to incessantly furnish the society with goods and services for the sustenance of both the present and upcoming generations (Balvanera et al., 2006; Mendoza-González et al., 2012; de Groot et al., 2012; Metzger et al., 2006; Giri, 2012). Globally, the conversion of the natural ecosystems into croplands, tree plantations, and urban areas have enormously increased food production, fiber, timber, housing, and other goods. Moreover, the gains generated an accompanying decline in the provision of several ecosystem services (Lawler et al., 2014) and about 60% of the ecosystems services have degraded in the past 5 decades (MEA, 2005).

There is a growing worldwide concern on how to reduce the harmful effects of economic development and urbanization on the natural ecosystems and the services they provide. However, a major challenge is that many of the services supplied by these ecosystems are public goods not captured by the market, thus, their economic values are not well understood (Costanza et al., 2014; McDonald et al., 2014; Yi et al., 2017). Quantifying ecosystem services and analyzing changes in their values is an important decision-support tool for the sustainable use of land (Förster et al., 2015) as it provides a useful approach for a complete evaluation of tradeoffs between alternative land-use options (Yi et al., 2017; de Groot et al., 2012).

For the valuation of ecosystem services, a group of four approaches are available in literature, including revealed preference approaches (e.g. market prices and travel cost), stated preference approaches (e.g. contingent valuation, and choice experiments), cost-based approaches (e.g. avoided cost and replacement cost) and benefits transfer (Talberth, 2015). Of these approaches, the benefits transfer method (BTM), a secondary valuation method, adapts previously established estimates from original (primary) valuation studies in one or more location to other areas assumed to have related demographics, economic and ecological characteristics (Plummer, 2009; Richardson et al., 2015; Yi et al., 2017). Since the 1990s, BTM has been widely used in a variety of natural resource and environmental policies contexts including water quality management (Luken et al., 1992), health risk assessment associated with water quality (Kask and Shogren, 1994), waste management (Brisson and Pearce, 1995) and forest management (Bateman et al., 1995). Most notably, the pioneering valuation study of Costanza et al. (1997) used BTM to extrapolate the global economic value of 17 ecosystem services provided by 16 main biomes. Afterwards, the estimates were updated (Costanza et al., 2014) based on a larger database of more than 300 case studies all over the world (de Groot et al., 2012). According to Costanza et al. (2014), the underlying data and models used for their assessment could be applied at multiple scales to assess changes in several ecosystem services.

While no ecosystem around the globe is free of the pervasive influence of human activities (Vitousek et al., 1997), the effect is more intense in the tropics through continuous removal of the tropical rainforests, which are the most biologically diverse of all terrestrial ecosystems (Laurance, 2010) and for which the biggest cause is expansion of agriculture (Geist and Lambin, 2001; Achard et al., 2002; Chakravarty et al., 2012). For example, between 1980 and 2000, more than 55% of new agricultural lands across the tropics were developed by clearing intact forests, and another 28% came from disturbed forests (Gibbs et al., 2010). Nigeria is no exception to this trend. Here, deforestation has been a continuous and increasing process for decades (FAO, 2010). Both forests and non-forests natural vegetation in the country have been seriously degraded during the last 40 years to make way for agricultural production (Abubakar, 2015; Abbas, 2009; World Bank, 1998).

As a result of concern over the imbalanced provision of economic and ecosystem services, the effects of LULC dynamics on the provisioning of ecosystem services has attracted increasing attention of academic researchers, policymakers and other stakeholders in recent years (Chen et al., 2014; Viglizzo and Frank, 2006). To this end, a substantial number of studies have assessed of the effects of the dynamics of LULC on ecosystem services throughout the world (e.g. Yi et al., 2017; Crespin and Simonetti, 2016; Kindu et al., 2016; Fei et al., 2016; Chen et al., 2014; Li et al., 2014; Long et al., 2014; Mendoza-González et al., 2012; Liu et al., 2011; Polasky et al., 2011; Zang et al., 2011; Li et al., 2010; Martínez et al., 2009); Hu et al., 2008; Li et al., 2007; Wang et al., 2006; Zhao et al., 2004 and Kreuter et al., 2001) many of which utilized the valuation coefficients of Costanza et al. (1997, 2014).

Although Quite a number studies have been conducted on LUCC change in several small regions of Nigeria (e.g. Abubakar, 2015; Abbas, 2009; World Bank, 1998; AC-Chukwuocha, 2015; Jibril and Liman, 2014; Ejaro and Abdullahi, 2013; Oyinloye and Oloukoi, 2012; Njoku et al., 2010; Mengistu and Salami, 2007), there is a paucity of information on LULC change at the national level with the few available studies (Abubakar, 2015; Abbas, 2009; World Bank, 1998) being conducted at such a coarse spatiotemporal resolution (with the exception of Abbas, 2009), noted to be too small for a meaningful analysis (Ademiluyi et al., 2008). Further, beyond analyzing the dynamics of LULC in Nigeria, a quantitative assessment to reveal the impact of these changes on ecosystem services value is seldom attempted. To date, there has been no assessment of these effects at a national scale and only few studies are recognized at the local level (Ayanlade, 2012; Ayanlade and Proske, 2016). Thus, we aim at closing the gaps of the previous LULC change studies in Nigeria by estimating changes in the economic value of ecosystem services in the wake of land-use/land-cover conversions in Nigeria between 2000 and 2010 using land-cover datasets with fine resolution of 30 m, which has become the standard for a good analysis of LULC change (Ramankutty et al., 2005). Such quantitative analyses are urgently needed in Nigeria, a country where the ever growing

population pressure and the corresponding increasing impact of human activities on the land have resulted in dramatic changes in LULC.

In 2017, Nigeria with an estimated population of 191 million (United Nations, 2017) is the most populous country in Africa and the seventh most populous worldwide. By 2050, it is expected that the country would be the world's third most populous with anticipated 411 million people (United Nations, 2017), which would represent a 115% increase. This unprecedented rise in population will further escalate the existing human pressure on the finite land resource with pressures on the environment and forest resource of the country already stretched beyond its limits from deforestation. Therefore, monitoring changes in LULC and their resultant impact on ecosystem services value (ESV) are crucial for decision making regarding the sustainable use of land and management of the natural ecosystems in Nigeria. We conducted our study to address two main questions; (1) How did LULC change unfold in Nigeria from 2000 to 2010? (2) How did the total ESV and the values of the individual ecosystem functions change in response to LULC dynamics during this period? This study hypothesized that the natural ecosystems services functions have degraded over time and that pattern changes in LULC play a vital role in this degradation.

2. Materials and methods

2.1. Study area

The study area covers the entirety of Nigeria, a country situated in the western part of Africa between 4°16′13.50″–13°53′31.24″ N latitudes and 2°40′6.35″–14°40′35.09″ E longitudes (Fig. 1) and with a total area of approximately 937,052.155 sq. km (NPC, 2010). It shares borders with Niger, Republic of Benin and Cameroon in the north, west and east respectively, while the Gulf of Guinea, an arm of the Atlantic Ocean forms the southern border. Administratively, Nigeria has 36 states and a Federal Capital Territory located in Abuja (Fig. 1). By virtue of a large north to south length of about 1100 km, Nigeria encompasses a wide range of climatic and ecological zones (Oginni and Adebamowo, 2013) and consequently a diverse pool of biodiversity (FGN, 2001). Nigeria has a variety of ecosystems; from mangroves and rainforests on the Atlantic coast in the south to the savannahs in the north (FRN, 2003).

2.2. LULC change analysis

We analyzed surface area changes in broad LULC types in Nigeria using the 2000 and 2010 global land-cover maps with 30 m grids downloaded from the database of the National Geomatics Centre of China (NGCC, 2014). These maps (entitled GlobeLand30) were generated via a pixel-object-knowledge (POK) based classification approach (Chen et al., 2015) using satellite images of Landsat TM/ETM+, Chinese Environmental Disaster Alleviation Satellite (HJ-1) and other ancillary data. An overall accuracy and kappa coefficient of respectively 79.6% and 0.81 in 2000, and 83.5% and 0.78 in 2010 were reported (Zhang et al., 2015; Zhang et al., 2016). GlobeLand30 delineate 10 LULC types, 8 of which are found in Nigeria (see Table 1 for a detailed description).

2.3. Assignment of ecosystem service values

We used the BTM-based value coefficients published by Costanza et al., 2014. We selected Costanza et al.'s valuation coefficients for use in our study for three main reasons; (1) they represented the most comprehensive set of valuation coefficients available to us providing estimates for 16 main biomes and 17 ecosystem service functions; (2) Valuation studies in Nigeria largely focused on the inland wetlands biome (e.g. Adekola et al., 2015; Barbier et al., 1991; Acharaya and Barbier, 2000; Gren and Soderqvist, 1994; Schuijt, 2002) and economic estimates are basically available for the provisioning services, which tends to underestimate the economic value of this biome since wetlands provide many other highly valued services (Costanza et al. (2014) that are as well recognized in Nigeria (Ajibola et al., 2015); and (3) the scope of our project did not allow us to estimate for other biomes in order to determine a total ESV. We compared the 8 LULC types in

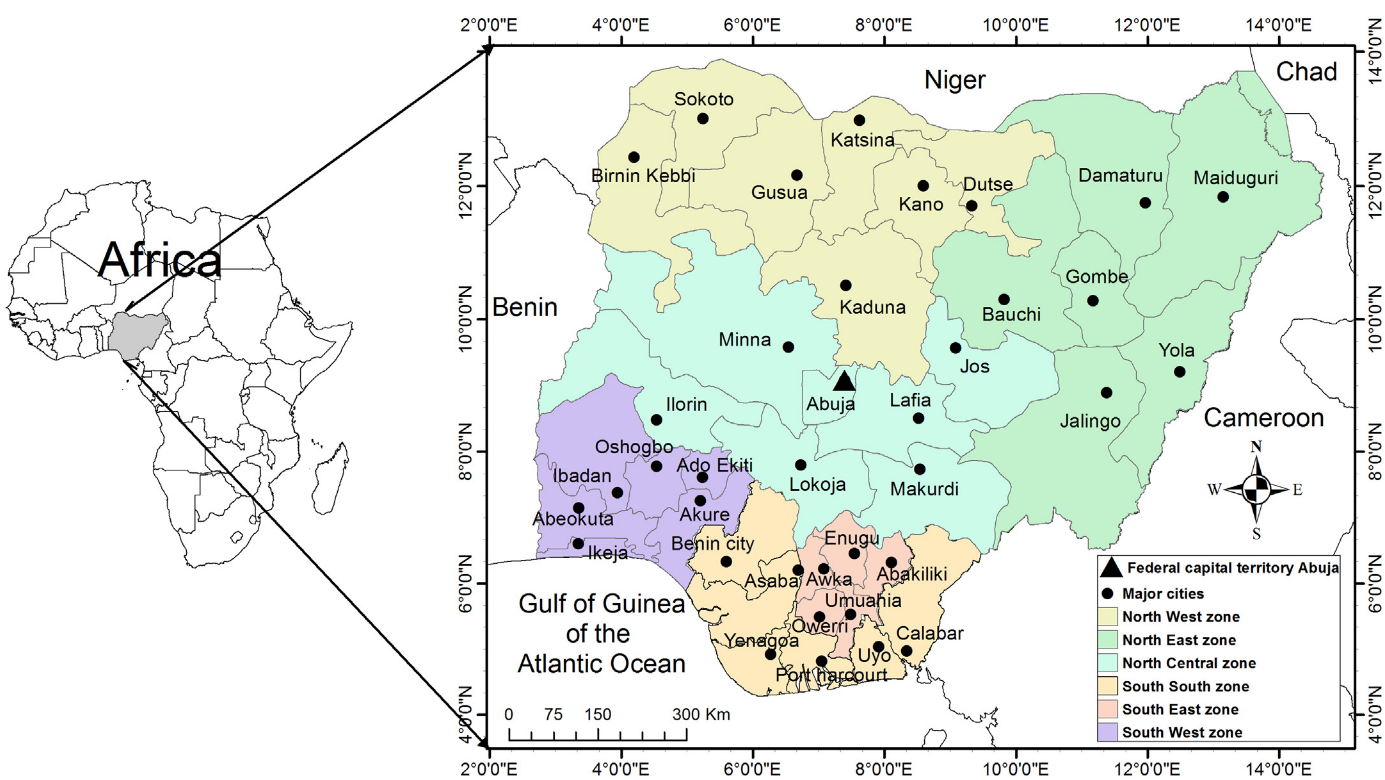

Fig. 1. Map showing the location of Nigeria, its geopolitical zones and major cities.

Table 1
GlobeLand30 description for the land-cover types in Nigeria.

Land cover type	Description
Cultivated land	Lands used for agriculture, horticulture and gardens, including paddy fields, irrigated and dry farmland, vegetation and fruit gardens, land for greenhouses economic cropland which is planted shrub crop or herbaceous crop, abandoned by the land reclamation of arable land.
Forest	Lands covered with trees with vegetation cover over 30%, including deciduous and coniferous forests, and sparse woodland with cover 10–30%.
Grassland	Lands covered by natural grass with a cover over 10% including typical grassland, meadow grassland, alpine grassland, desert grassland.
Shrubland	Lands covered with shrubs with a cover over 30%, including deciduous and evergreen shrubs and desert steppe with a cover over 10%.
Wetland	Lands covered with wetland plants and water bodies, including inland marsh, lake swamp, sea marsh, river floodplain wetlands, forest/shrub wetlands, peat bogs, mangrove and salt marsh, etc.
Water bodies	Water bodies in the land area, including river, lake, reservoir, fish pond, etc.
Built-up land	Lands modified by human activities, including all kinds of habitation, industrial and mining area, transportation facilities, and interior urban green zones and water bodies.
Bare land	Lands with vegetation cover lower than 10%, including desert, sandy fields, Gobi, gravel, bare rocks, saline and alkaline lands, microbiotic crust.

Nigeria (Table 1) with the 16 biomes identified by Costanza et al. (2014) and the nearest equivalent biome was used as a surrogate. Cropland was used as a proxy for cultivated land, tropical forest for forests, grass/rangelands for grasslands and shrublands, urban for built-up land and desert/tundra/ice and rock for bare land. Since grasslands and shrublands have the same equivalent biome we lump them together in the analysis and are hereafter referred to as savannahs (Table 2).

Table 2
Costanza et al. (2014) ESV coefficients (US\$ha^{-1} yr^{-1}) of the equivalent biomes for the LULC types in Nigeria.

Service type	Sub-type	CL[a]	FS	SH	WL	WB	BU	BL
Provisioning	Food production	2323	200	1192	952	106	0	0
	Raw materials	219	84	54	416	0	0	0
Regulating	Gas regulation	0	12	9	0	0	0	0
	Climate regulation	411	2044	40	200	0	905	0
	Disturbance regulation	0	66	0	4596	0	0	0
	Water regulation	0	8	3	1789	7514	16	0
	Water supply	400	27	60	959	1808	0	0
	Waste treatment	397	120	75	111345	918	0	0
Supporting	Erosion control	107	337	44	3507	0	0	0
	Soil formation	532	14	2	0	0	0	0
	Nutrient cycling	0	3	0	577	0	0	0
	Pollination	22	30	35	0	0	0	0
	Biological control	33	11	31	303	0	0	0
	Habitat/refugia	0	39	1214	12452	0	0	0
	Genetic resources	1042	1517	1214	243	0	0	0
Recreation and culture	Recreation	82	867	26	2199	2166	5740	0
	Cultural	0	2	167	636	0	0	0
Total ecosystem value		5568	5381	4166	140174	12512	6661	0

[a] CL, FS, SH, WL, WB, BU and BL refers to cultivated land, forests, savannah, wetland, water bodies, built-up land and bare land respectively.

2.4. Calculation of ESV

To calculate the total ESV in Nigeria and each state, we referred to Costanza's ESV assessment model (Costanza et al., 1997) as well used in other studies (e.g. Yi et al., 2017; Li et al., 2007; Wang et al., 2006; Zhao et al., 2004; Kreuter et al., 2001) as follows:

$$ESV_t = \sum_{k=1}^{n} (A_{kt} \times VC_k) \tag{1}$$

where; ESV_t is the estimated total ESV at time t, A_{kt} is the area (ha) of LULC type k at time t and VC_k is the ecosystem services value coefficient (US\$ha^{-1} yr^{-1}) of the LULC type k.

The change in ESV over time was assessed using the formula:

$$ESV_{cr} = \frac{ESV_{t_2} - ESV_{t_1}}{ESV_{t_1}} \times 100\% \tag{2}$$

In this expression, ESV_{cr} is the change rate of ESV during the observation period t_1 to t_2, ESV_{t_2} and ESV_{t_1} is the estimated total ESV at the end and beginning of the observation period, t_2 and t_1 respectively.

In addition to quantifying the impact of LULC change on the total ESV in Nigeria, we also estimated the impact of such changes on the individual ecosystem functions. The values of services provided by individual ecosystem functions were calculated using the following equation:

$$ESV_{ft} = \sum_{k=1}^{n} (A_{kt} \times VC_{fk}) \tag{3}$$

where; ESV_{ft} is the estimated ESV of function f at time t, A_k and VC_k are the area (ha) and the ecosystem service value coefficient of function f (US\$ha^{-1} yr^{-1}) for the LULC type k.

3. Results

3.1. LULC patterns in Nigeria

The spatial distribution of the patterns of Nigeria's LULC in 2000 and 2010 is presented in Fig. 2. In 2000, savannahs represented the most dominant LULC class, covering about 44.5% of the total area. The areas under cultivation and forests were also large, with proportions of 26.2% and 24.4%, respectively, while the remaining LULC types (wetland, water bodies, built-up land and bare land) make up only 4.9% of Nigeria's total land area (Table 3).

The spatial distribution of these major LULC types exhibited regional variation in 2000 (Fig. 2). At this time, savannahs were mainly distributed in the northern states, including Borno (11.4%), Yobe (7.9%), Bauchi (7.3%), Niger (7.1%), Kebbi (6.0%), Taraba (5.9%), Kaduna (5.7%), Sokoto (5.2%), Kogi (4.5%), Adamawa (4.5%), Zamfara (4.2%), Nassarawa (3.8%), Plateau (3.8%) and Benue (3.4%), together accounting for 80.8% of the total savannahs. Cultivated land was concentrated in the northern region (91.8%); chiefly in 11 of the states in the region namely; Katsina (7.9%), Niger (7.5%), Jigawa (6.4%), Borno (6.4%), Kano (6.3%), Bauchi (6.2%), Taraba (6.1%), Benue (5.7%), Kaduna (5.6%), Zamfara (5.4%) and Yobe (5.2%) states, which together accounted for more than half (68.6%) of cultivated land in the region. Above half of the total forests (56.4%) were distributed in Kwara (12.0%) and Niger (10.3%) states in the Northcentral; Taraba state (9.0%) in the Northeast; Cross river state (6.2%) in the South-south; and Oyo (9.5%), Ogun (5.0%) and Ondo (4.4%) states in the Southwest. The wetlands were concentrated in Borno state in the Northeast (22.2%) and three coastal southern states, including Bayelsa (22.2%), Delta (19.2%) and Rivers (12.8%) states. Water bodies were found largely in Niger (16.5%), Borno (12.9%), Kebbi (10.2%) and Lagos (7.8%) states. Built-up lands were mainly scattered around the major cities of all the regions while bare land was concentrated in Sokoto (30.8%) and Borno (28.0%) states,

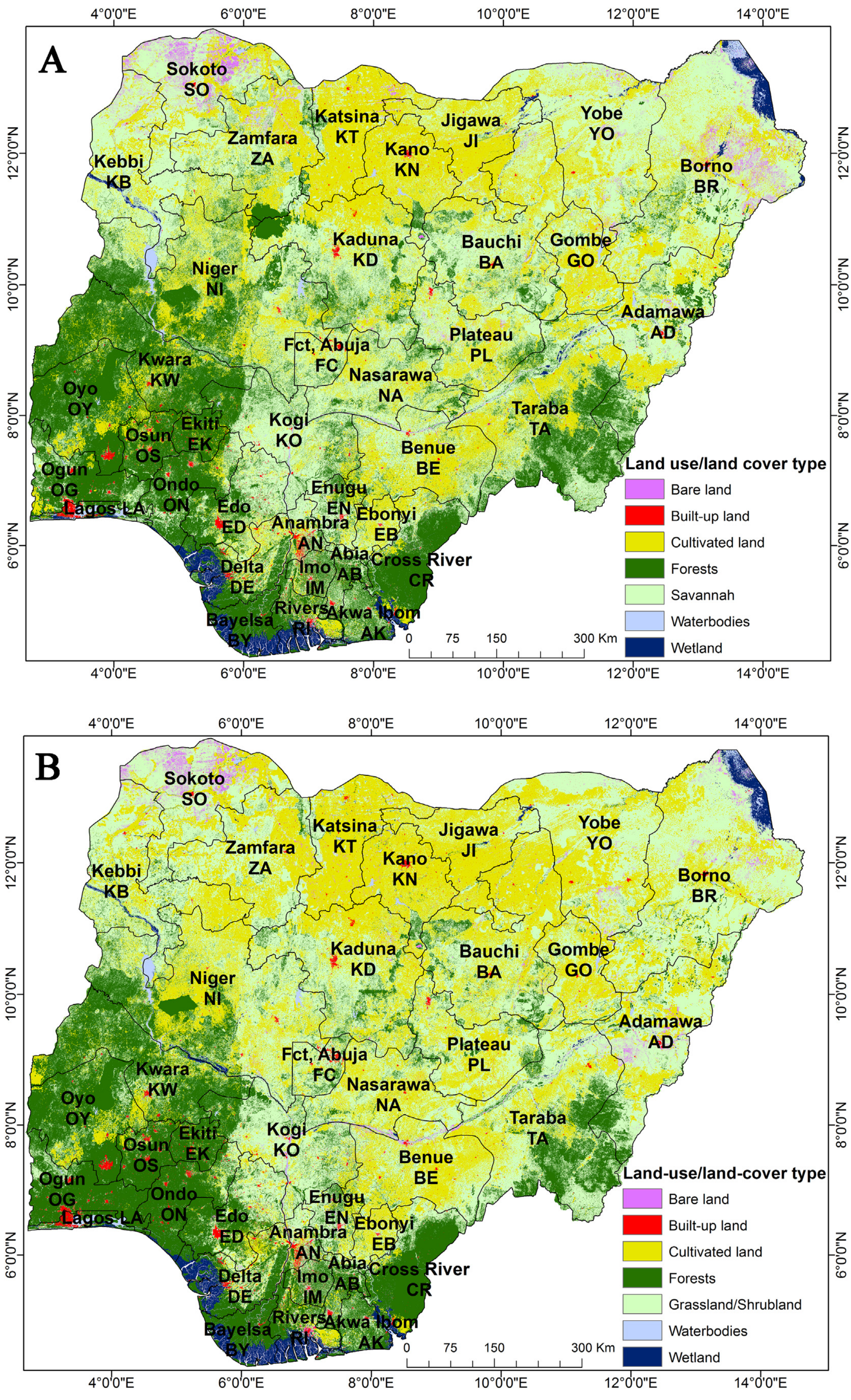

Fig. 2. Spatial distribution of LULC in Nigeria in (a) 2000 and (b) 2010.

Table 3
Conversion matrix of LULC change (sq. km) in Nigeria from 2000 to 2010.

2010	2000							Total area 2000
	[a]CL	FS	SH	WL	WB	BU	BL	
Cultivated land	*192,036.41*	4970.69	45,752.83	72.26	127.00	785.27	1081.72	244,826.19 (26.16)
Forests	13,956.08	*166,368.72*	46,234.01	1027.11	313.43	359.71	286.43	228,545.48 (24.42)
Savannah	82,809.36	33,462.05	*292,783.28*	644.64	425.29	956.30	5149.44	416,230.37 (44.48)
Wetland	76.32	912.51	1488.75	*12,284.93*	608.81	9.06	25.84	15,406.22 (1.65)
Water bodies	277.32	478.13	952.30	1062.40	*6664.82*	7.17	329.29	9771.44 (1.04)
Built-up land	350.84	209.50	489.83	9.35	6.54	*6481.88*[b]	34.86	7582.80 (0.81)
Bare land	2212.35	207.63	6360.08	130.24	170.80	39.73	*4239.11*	13,359.94 (1.43)
Total area 2010	291,718.68 (31.18)	206,609.24 (22.08)	394,061.07 (42.11)	15,230.94 (1.63)	8316.69 (0.89)	8639.12 (0.92)	11,146.69 (1.19)	
Direction of change	↑	↓	↓	↓	↓	↑	↓	

The numbers in parenthesis indicates percentages of each LULC types for the respective years.
The diagonal values (in italics) represent the area of each LULC class that remained stable from 2000 to 2010 while the off diagonal values represent the change area.
[a] CL, FS, SH, WL, WB, BU and BL refers to cultivated land, forests, savannah, wetland, water bodies, built-up land and bare land respectively.
[b] While we expect stability of built-up land, ≈1101 sq. km of built-up land changed to other LULC types from 2000 to 2010, please refer to Arowolo and Deng (2018) for possible reasons of instability during this period in Nigeria.

respectively in the extreme Northwest and extreme Northeast where natural conditions are harsh.

3.2. LULC change 2000–2010

During the period of 2000–2010, cultivated land and built-up land increased while other LULC types decreased (Table 3). The expansion of cultivated land was rapid at a rate of 1.92% per annum, resulting in a total growth of 46,892.80 km^2 during the study period, which is 1.78% higher than the combined area of wetland, water bodies, built-up land and bare land in 2000. The total expansion of built-up land was about 1056.65 km^2 at an annual rate of 1.39%. With regards to their initial surface area in 2000, in 2010 bare land suffered the highest loss of 16.57%, followed by water bodies, forests and savannahs with losses of 14.89%, 9.60% and 5.33% respectively, while wetland had the least decrease of 1.13%.

In order to show the spatial hotspots of change from 2000 to 2010 for the different LULC types, we calculated the grid-based change intensity using the ArcGIS software spatial block statistics tool. Here, the change map for each LULC type is partitioned into non-overlapping blocks of 15 km by 15 km and the statistics of the land-use change information in each grid is calculated. The spatial distribution of the change hotspots is shown in Fig. 3. During this epoch, the northern region can be characterized by cultivated land expansion and the southern region showed a trend towards forests increase. Cultivated land increased across all the states in the northern region (except in Taraba and Abuja) and largely in Bauchi (9243.87 km^2), Yobe (6666.47 km^2), Niger (6134.09 km^2), Kaduna (4113.62 km^2), Nassarawa

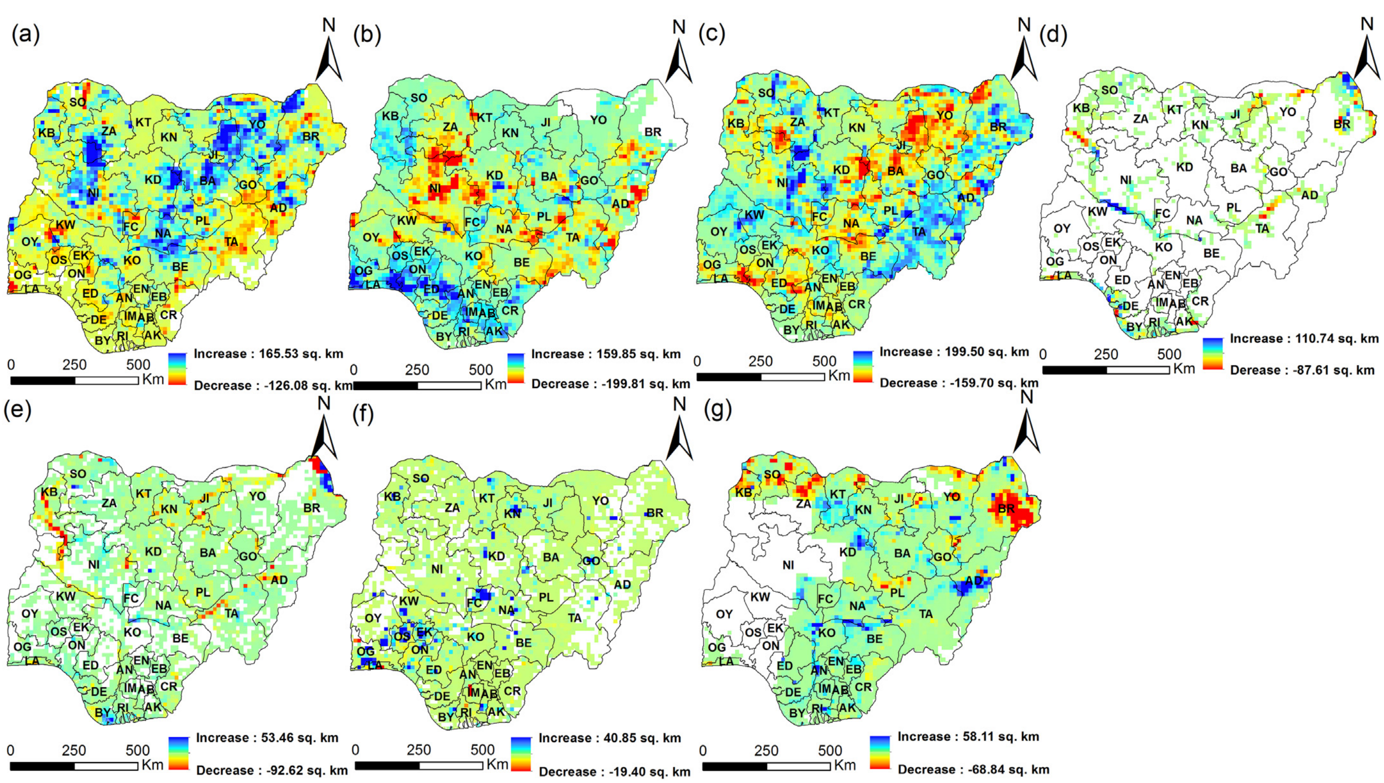

Fig. 3. Hotspots of change in different categories of LULC from 2000 to 2010 for (a) Cultivated land (b) Forests (c) Savannahs (d) Wetlands (e) Water bodies (f) Built-up land (g) Bare land.

(4069.38 km^2), Borno (3813.04 km^2), Kebbi (3785.48km^2), Zamfara (2998.00 km^2) and Benue (2392.76 km^2) states, together accounting for 92.2% of the total net gains to cultivated land in the country. The southern states, by contrast, experienced cultivated land decrease excluding Rivers, Edo, Enugu, Ebonyi and Abia States, which in total gained 952.54 km^2, only 2.0% of the country-wide expansion. Forests decreased across all the northern states (substantially in Niger, Taraba, Kaduna, Zamfara, Adamawa, Kwara and Nasarawa states) with the exception of Abuja, Jigawa, Kebbi and Sokoto where forests increased by a total amount of 635.81 km^2. On the contrary, apart from Enugu, Bayelsa and Oyo states, with an aggregated loss of 978.98 km^2 forested lands, the states in the southern region experienced forests growth (largely in Edo, Ogun and Ondo states).

The contraction of Savannah was observed across all the geopolitical zones of the country except in the northern states of Kwara, Niger, Adamawa, Borno, Taraba, Katsina and Zamfara, where savannahs increased by an aggregate of 12,998.16km^2; and in the southern states of Ekiti and Oyo, with a total savannahs land gain of 1155.93km^2. The decrease of savannah was considerable for Bauchi, Yobe, Kebbi and Nasarawa states in the North and Ogun, Ondo and Edo states in the South. Built-up land expanded across the country except in Anambra, Imo and Rivers states, which jointly loss about 30 km^2. The contraction of built-up land as observed for these states is consistent with the findings of AC-Chukwuocha (2015) that 74.68 ha of built-up lands in Owerri (capital of Imo state) converted to other LULC types mainly farmland, vegetation and bare surfaces during the period of 1977 to 2012 and Amnesty International (2011) who estimated that about 375 structures were demolished from the Njemanze waterfront in Port Harcourt (capital of Rivers state) between 2008 and 2010 subsequent to the redevelopment plan of the State Government.

Wetland decrease was profound in Borno, Taraba, Yobe, Kebbi and Lagos states, while reduction of water bodies hotspots were Niger, Borno, Taraba, Yobe, Jigawa and Kebbi states. Hotspots of bare land decrease include Borno, Sokoto, Zamfara, Kebbi, Yobe and Plateau states. It can be seen from change intensity maps that the main processes of LULC changes were the conversions between the major LULC types of cultivated land, forests and savannah. The hotspots of forests and savannahs shrinkage were heavily threatened by the expansion of cultivated land (Fig. 3). Quantitatively, as revealed by the land change matrix (Table 3), conversions between cultivated land, forests and savannahs resulted into net losses of 898.54 km^2 and 3705.65 km^2 per year from forests and savannahs respectively to cultivated land, which represents about 98.19% of the total per annum expansion to cultivated land. This severe reduction in the natural vegetation coupled with a decline in the wetland and water bodies ecosystems during the study period emphasize a severe dwindle in the ecologically important categories of LULC in Nigeria and a corresponding increase in production oriented land uses, which implies increasing human encroachment into the natural ecosystems.

3.3. Estimated changes in ecosystem services

3.3.1. Change in total ESV

Based on Costanza et al. (2014) ecosystem services value coefficients, in 2000, the total ESV in Nigeria was estimated at 665.93 billion US$ (Table 4). Of this value, wetlands contributed the highest (about 32.43%), although it covered only a small proportion (1.65%) of the entire landscape. The percentage contribution of savannahs, cultivated land and forests were also large, in the order of 26.04%, 20.47% and 18.47%. Water bodies accounted for 1.83% of the total ESV while built-up land contributed least to the total ESV, only 0.76%.

During the period of 2000–2010, ESV in Nigeria from the natural ecosystems (i.e. forests, savannahs, wetlands and water bodies) decreased by 4.83%, from 52.46 billion US$ per year to 49.93 billion US$ per year (Table 4). Of the total ESV loss by these natural landscapes, change in tropical forests was responsible for the largest, accounting for 46.64%, followed by Savannah with 36.48% contribution, while wetland land and water bodies decrease accounted for 9.68% and 7.19% of the total loss respectively. In contrast, the total ESV of the artificial (human-modified) ecosystems (i.e. cultivated and built-up land) increased by 18.97%, from 14.14 billion US$ per year to 16.82 billion US$ per year, 97.38% of which was contributed cultivated land increase. On the overall, the total ESV in Nigeria increased by 1.51 billion US$ from 2000 to 2010, at a rate of 0.023% per year.

Analysis of the total ESV for the administrative states (Fig. 4) shows that ESV was highest for Borno state (79.67 billion US$), in 2000, followed by Bayelsa (51.66 billion US$), Delta (48.75 billion US$), Niger (38.16 billion US$), Taraba (35.93 billion US$) and Rivers (31.24 billion US$) states. The ESV for these states was mainly contributed by the wetland ecosystem in Borno (60.2%), Bayelsa (92.8%), Delta (85.03%), and Rivers (88.67%); forests in Niger (33.3%) and Taraba (30.94%); and savannahs in Borno (51.77%). ESV was generally low in Southeast Nigeria and Anambra state in the region had the lowest ESV (2.33 billion US$) in 2000 with main contributions from savannahs (44.52%). From 2000 to 2010, ESV decreased in 13 of the 37 states (including the capital territory). The rate of decrease was highest for Lagos state (−23.01%), followed by Taraba (−11.1%), Yobe (−10.0%) and Kebbi (−8.4%) while it was lowest of Ekiti state with a change rate of −0.2%. For states with increased ESVs, Niger has the highest rate of increase (16.9%) and next are Ondo (7.9%), Kwara (6.7%), Sokoto (6.6%) and Nassarawa (5.8%) states while Benue state has the lowest increasing rate of 0.4%.

3.3.2. Changes in values of ecosystem service functions in Nigeria

We also quantified and compared the contributions of each ecosystem functions to the overall ESV in Nigeria (Table 5). Breaking down the total ESV for Nigeria in 2000 and 2010, the most important components were food production, waste treatment, habitat/refugia and genetic resources. These ecosystem service functions in 2000 respectively contribute 16.91%, 28.23%, 10.60% and 16.68% of the total, and 18.04%, 28.07%, 10.13% and 16.47% of the total in 2010 respectively. The breakdown of the total change from 2000 to 2010, showed a decline for all the ecosystem services function except for food production, raw materials, water supply, soil formation and biological control, which increased respectively by 6.91%, 7.04%, 8.69%, 18.32%, and 2.02%. During the study period, the ESV of water regulation decreased more rapidly than any other ecosystem service (−11.01%), followed by gas regulation (−7.09%), cultural (−4.84%), climate regulation (−4.30%), habitat/refugia (−4.24%) and recreation services (−4.04%). The rate of change of ESV_f was lowest for waste treatment (−0.35%).

Table 4
Ecosystem services value (ESV) by land use type and the change in Nigeria from 2000 to 2010.

	CL[a]	FS	SH	WL	WB	BU	BL	TOTAL
ESV 2000 (10^9 USD)	136.32	122.98	173.40	215.95	12.23	5.05	0.00	665.93
ESV 2000 (%)	20.47	18.47	26.04	32.43	1.83	0.76	0.00	100
ESV 2010 (10^9 USD)	162.43	111.18	164.17	213.50	10.41	5.75	0.00	667.44
ESV 2010 (%)	24.34	16.66	24.59	31.99	1.56	0.86	0.00	100
ESV change 2000–2010 (10^9 USD)	26.11	−11.80	−9.23	−2.45	−1.82	0.70	0.00	1.51
ESV change 2000–2010 (%)	19.15	−9.60	−5.32	−1.13	−14.88	13.86	0.00	0.23

[a] CL, FS, SH, WL, WB, BU and BL refers to cultivated land, forests, savannah, wetland, water bodies, built-up land and bare land respectively.

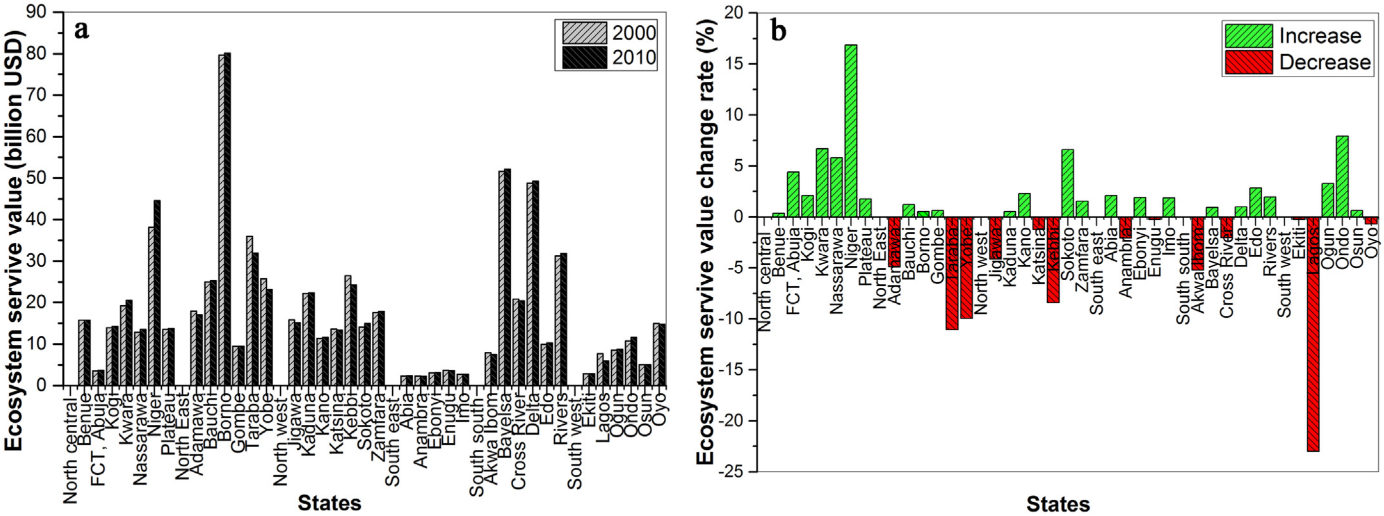

Fig. 4. (a) Ecosystem service value (billion US$), (b) Ecosystem service value change rate (%) from 2000 to 2010.

3.3.3. Spatial patterns of change in the value of ecosystem service functions

The rate of change in ecosystem service functions values in the different states are displayed in Fig. 5. For the ecosystem service functions of food production, raw materials, water supply, soil formation and biological control that increased in value at the national level, increments were mainly contributed by states in the northern region. These functions increased across the region except for Abuja (with decrease in food production, raw materials and biological control functions), Kwara (with decrease in raw materials), Katsina (with decrease in water supply), Taraba (with decrease in raw materials, water supply and soil formation) and Yobe, Jigawa and Kebbi states with decreases in the service function of biological control. The rate of increase was highest in Nasarawa state for food production (18.50%) and water supply (36.29%); in Bauchi state for raw materials (27.72%) and soil formation (59.96%); and in Niger state for biological control (17.66%). On the contrary, these functions decreased markedly for the southern states. More than three-quarter of the states experienced a decrease in food production (82.35%) and biological control (76.5%) while raw materials, water supply and soil formation functions decreased in more than half of the states, respectively 58.8%, 64.7% and 70.6%. The rate of decrease was highest in Ogun for food production (−43.42%), water supply (−37.05%) and soil formation (−63.78%) and in Lagos for raw materials (−12.77%) and biological control (−29.70%).

Amongst the ecosystem functions that decreased at the country level, the decrease in the functions of pollination, habitat/refugia and cultural was evident in the majority of the administrative states. Pollination decreased in about three-quarter of the states (75.7%) and the change rate range from −0.36% (in Katsina) to −7.62% (in Bauchi) while habitat/refugia and cultural functions decreased in more than 70% of the country and the change rates varies respectively from −0.23% (in Katsina) and − 1.00% (in Sokoto) to −46.42% and − 51.35% in Ogun state. The rate of decrease in the ESV of gas regulation, climate regulation, disturbance regulation, water regulation, waste treatment, erosion control, nutrient cycling, genetic resources and recreation was significant in the northern region compared to the southern region. With the exception of Taraba state, the value of gas regulation decreased in all the northern states, waste treatment and climate regulation values respectively decreased in 40% and 60% of the states and more than 60% of the states witnessed decline in the values of disturbance regulation, water regulation, erosion control, nutrient cycling, genetic resources and recreation. In contrast, all these functions increased in more than 50% of the southern states and notably above 80% of the states have increments in the values of climate regulation, erosion control and recreation services functions.

The rate of decrease in the north ranges from −0.14% (in FCT, Abuja) to −26.13% (in Kano), −5.93% (in Katsina) to −36.63% (in Zamfara), −2.09% (in Borno) to −82.38% (in Yobe) and − 0.42% (in Niger) to −81.37% (in Yobe) respectively for gas, climate, disturbance and water regulations functions whereas they decreased respectively within the range of −0.02% (in Oyo) to −9.96% (in Ebonyi), −0.60% (Bayelsa) to −3.80% (in Enugu), −0.96% (in Anambra) to −32.09% (in Lagos) and − 0.30% (in Delta) to −8.59% (in Akwa ibom) in the south. Waste treatment, erosion control and nutrient cycling decreasing rates ranges in the north are −1.24% (in Borno) to −63.81% (in Yobe), −1.28% (in Borno) to −21.88% (in Adamawa) and −1.76% (in Borno) to −83.41% (in Yobe) respectively while the southern states ranges of decrease are from −4.43% (in cross river) to −34.73% (Lagos), −2.77% (in Enugu) to −18.51% (in Lagos) and −1.93% (in Oyo) to −34.23% (in Lagos). The range of genetic resources value decrease rate in the north was −0.64% (in plateau) to −5.32% (in Nasarwa) while it was −0.77% (in Bauchi) to −40.44% (in Zamfara) for recreation function. In contrast, genetic resources and recreation functions rates of decrease in the south vary from −0.65% (in Oyo) to −1.58% (in Bayelsa) and −1.88% (in Oyo) to −3.29% (in Enugu) respectively.

Table 5
Estimated values for different ecosystem functions (ESV_f) in Nigeria in 2000–2010.

Service type	Sub-type	2000	2010	2000–2010	
		10^9 USD	10^9 USD	10^9 USD	%
Provisioning	Food production	112.629	120.409	7.780	6.908
	Raw materials	10.170	10.886	0.716	7.040
Regulating	Gas regulation	0.649	0.603	−0.046	−7.088
	Climate regulation	59.436	56.88 4	−2.552	−4.294
	Disturbance regulation	8.589	8.364	−0.225	−2.620
	Water regulation	10.418	9.271	−1.147	−11.010
	Water supply	16.152	17.555	1.403	8.686
	Waste treatment	188.022	187.374	−0.648	−0.345
Supporting	Erosion control	17.555	17.160	−0.395	−2.250
	Soil formation	13.428	15.888	2.460	18.320
	Nutrient cycling	0.958	0.941	−0.017	−1.775
	Pollination	2.681	2.641	−0.040	−1.492
	Biological control	2.816	2.873	0.057	2.024
	Habitat/refugia	70.606	67.611	−2.995	−4.242
	Genetic resources	111.086	109.949	−1.137	−1.024
Recreation and culture	Recreation	32.762	31.439	−1.323	−4.038
	Cultural	7.977	7.591	−0.386	−4.839
	Total	665.934	667.439	1.505	0.226

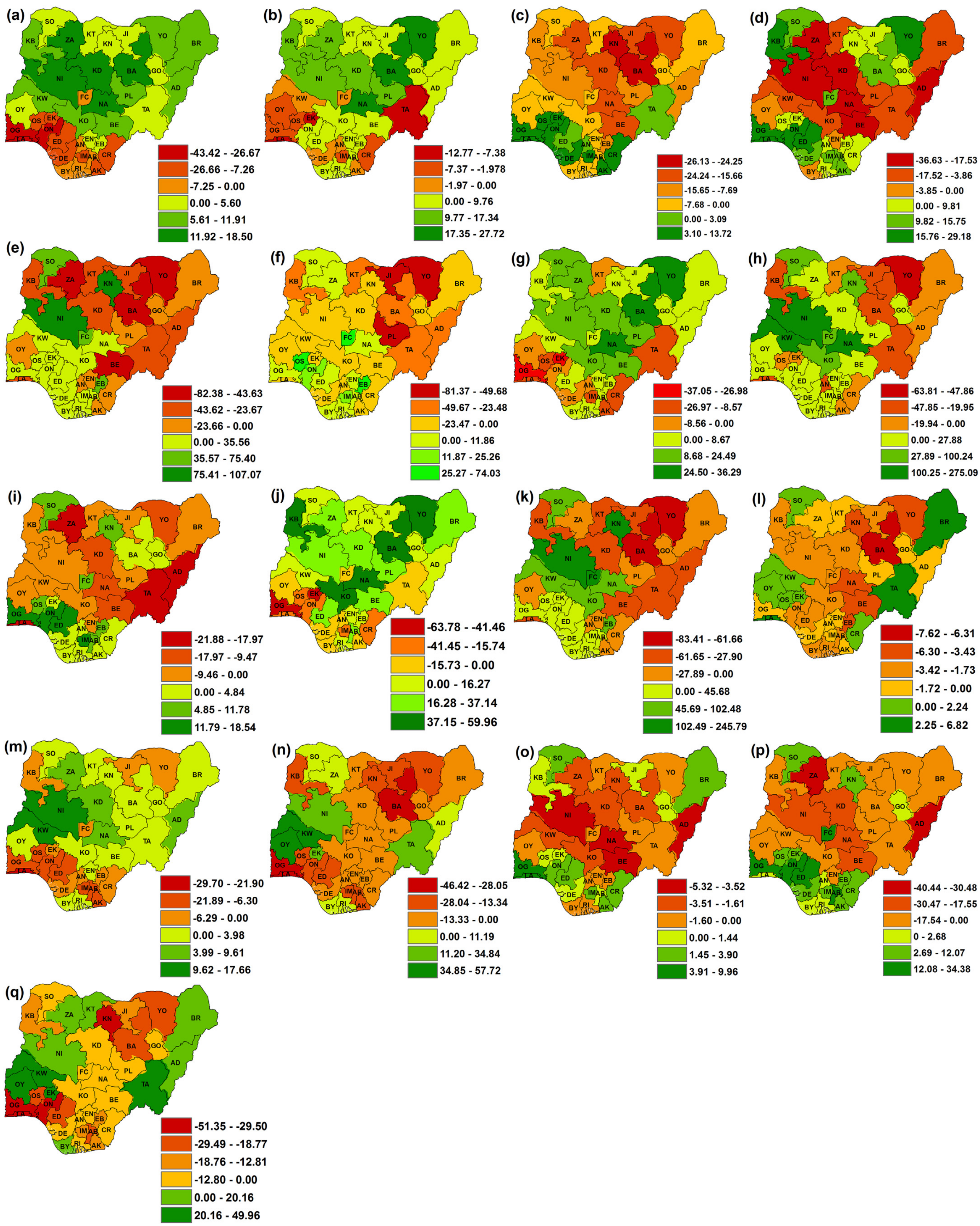

Fig. 5. Value change rates (%) for ecosystem functions of (a) food production (b) raw materials (c) gas regulation (d) climate regulation (e) disturbance regulation (f) water regulation (g) water supply (h) waste treatment (i) erosion control (j) soil formation (k) nutrient cycling (l) pollination (m) biological control (n) habitat/refugia (o) genetic resources (p) recreation (q) cultural.

4. Discussion

4.1. Impact of LULC change on ecosystem services in Nigeria

In Nigeria, loss of the natural vegetation into cultivated land has been the most recurrent LULC change as evident from previous studies (Abubakar, 2015; Abbas, 2009; World Bank, 1998) and the present study. Based on the estimated size of the seven LULC categories and using Costanza et al. (2014) ecosystem services value coefficients for related biomes, we determined that the total ESV in Nigeria increased by 0.23% (1.51 billion US$) from 2000 to 2010. This positive change was mainly due to the huge increase in ecosystem services due to cultivated land expansion, which more than offset the decrease in ecosystem services due to the loss of the forests, savannahs and other natural ecosystems during this period. At the states level, positive change in states with increased total ESV from 2000 to 2010 is attributable to the expansion of cultivated land and wetland for the northern states and the growth could be associated to forests and wetland increase for states in the southern region (Fig. A.1, Supplementary information). The decline in ESV in states with a negative change in total ESV during the study period was mainly contributed by the decrease in the areas of the natural landscapes mainly wetland, savannahs and forests in the northern region, while the loss of wetland mainly accounts for the reduced ESV in the southern states (Fig. A.1, Supplementary information).

In contrast to our finding, studies in other regions of the world that reported agricultural expansion and with ESV assessment procedure similar to ours determined a decrease in total ESV (e.g. Li et al., 2007; Zhao et al., 2004; Wang et al., 2006). Amongst several other reasons, the difference in the valuation coefficients used could be responsible. These studies used Costanza et al. (1997) valuation coefficients which differ greatly from the Costanza et al. (2014) coefficients partly as a result of the larger number of case studies being used to obtain values for each biome in 2014 (Yi et al., 2017). The coefficient values in 2014 are substantially larger by ~4284% for cropland, ~94% for forests, ~1202% for grassland/rangelands, ~587% for wetland, ~7% for water bodies and most notably is the increase in ecosystem service value of urban areas from $0 in 1997 to $6661/ha/year in 2014. When Costanza et al. (1997) valuation coefficients are applied in Nigeria (Table A.1, Supplementary information), the total annual ESVs were much lower (122.58 billion US$ in 2000 and 114.34 billion US$ in 2010) and total ESV decreased by 6.73% (824.85 million US$ per annum) from 2000 to 2010 in contrast to when 2014 valuation coefficients (Costanza et al., 2014) were used. However, the direction of change for the specific land cover types (except for built-up land) using Costanza et al. (1997) valuation coefficients remained consistent with that of 2014 (Fig. A.2, Supplementary information), which indicates the negative impact of cultivated land expansion on the ecosystem services value of the natural ecosystems regardless of the valuation coefficients used.

Even though the Total ESV increased in Nigeria during the study period using the updated valuation coefficient (Costanza et al., 2014), the severe ecosystem services value loss from the natural ecosystems given their substitution by the anthropogenic landscapes is worth noting. Conversions between cultivated land and the natural landscapes led to a net ESV loss of 4835.03 million US$ from the forests, 15,437.75 million US$ from savannahs, 56.85 million US$ from the wetland, and 188.08 million US$ from water bodies, which represented 3.91% of their total ESV in 2000. Forest loss accounts for the largest share of the total decline in the services value of the natural ecosystems in Nigeria. This is consistent with the findings of Ayanlade (2012) who found that forests degradation contributed greatest to the reduction in ecological service value in the Niger Delta of Nigeria.

Land-use change into the agriculture in Nigeria largely led to increased food production and raw materials (as also evidenced worldwide; Lawler et al., 2014) as well as the service functions of soil formation, biological control and water supply, however the gains generated are accompanied by decline in the provision of 70% out of the 17 specific ecosystem services considered in this study, which are largely provided by the natural ecosystems. This aligns with findings of numerous studies worldwide that agriculture and urban expansion are negatively affecting the provision of other key ecosystem services such as nutrient cycling, climate regulation (Li et al., 2007; Peng et al., 2006), erosion control and genetic resources (Portela and Rademacher, 2001), disturbance regulation (Zhao et al., 2004; Wang et al., 2006), soil fertility (Schroter et al., 2005; Collard and Zammit, 2006), recreation opportunities (Nahuelhual et al., 2014) and water regulation (Schroter et al., 2005; Fiquepron et al., 2013). The consequences of declining services such as climate and water regulation have already been felt in Nigeria through floods incidence, the most common environmental hazards in the country (Etuenovbe, 2011), which over the years has led to substantial amount of casualties and economic loss, affected soil quality, contaminated water resources and increased the risk of diseases (Ubuoh et al., 2016; Prekeyi et al., 2015; Anthony and Edem, 2015; Utsev et al., 2015).

Although expansion of land under agriculture in Nigeria is attributable to ensuring food security of the large growing population (Abubakar, 2015; World Bank, 1998), food production is yet to keep pace with population increase (Abdulrahaman, 2013; Uma et al., 2014; Ahungwa et al., 2014) and more than half of the population are still food insecure (Ojo and Adebayo, 2012) ranking the country 38th out of 76 on the 2014 Global Hunger Index (IFPRI, 2015). Food insecurity in Nigeria may be attributable to the low productivity of the agricultural sector given the constraints that militates against the sector including climate change, insecure land tenure, lack of access to credit, poor funding, heavy dependence on rain fed agriculture, poor irrigation facilities amongst others (Nwajiuba, 2013; Ojo and Adebayo, 2012), which have reduced labour supply in the sector and resulted into decline in agricultural output and (Apata et al., 2009; Uma et al., 2014). As a result, Nigeria's large, growing population has become dependent on imported food staples for survival (Idachaba, 2009; Ogbalubi and Wokocha, 2013; Nwajiuba, 2013).

With the continuous decrease in the natural ecosystems and their associated services, some of the constraints to the agricultural sector will become exacerbated and consequently, agricultural productivity will be further threatened. For example, a further decline in the climate regulation service caused by clearing the forests will exacerbate climate warming, one of the most serious environmental threats, which will, in turn, affect the productivity of the agricultural sector amongst several other consequences. For example, it is projected that crop yield in Africa may fall by 10–20% by 2050 or even as high as 50% due to climate change (Jones and Thornton, 2002). Nigeria will be no exception to this, a highly climate vulnerable country and with low adaptive capacity (Apata et al., 2009; Joiner et al., 2012) given the sole dependence of its agricultural sector on the natural resource base (Nwajiuba, 2013).

4.2. Limitations of the study and area of future research

There are several limitations of the methodology of benefit transfers which we have adopted here. For example, a major error is that by generalizing the unit values derived from one area for a specific good as average unit values in all other areas, the approach assumes homogeneity of ecosystems services value within the entire biome/LULC types (Schmidt et al., 2016; Crespin and Simonetti, 2016; Kindu et al., 2016). However, some services may be more beneficial in some areas than others (Eigenbrod et al., 2010; Yi et al., 2017). Also, BTM method is considered to be valid only after empirical links between ecosystem characteristics and final services have been established (Richardson et al., 2015; Wong et al., 2015). Nevertheless, despite the shortcomings of the BTM, the approach is often the best or sole option available to resource managers and policy analysts for a timely assessment of multiple ecosystem services at large geographical scales such as regional and national scales when primary data at these scales are not available (Wong et al., 2015). Thus, BTM will continue to play a crucial role within the

field of ecosystem services valuation (Richardson et al., 2015). Moreover, the financial constraint for the collection of primary data in developing countries such as Nigeria often dictates that benefit transfer is the only feasible option.

Though absolutely precise value coefficients is often said to be likely less critical if the aim is to assess the directional changes in ESV over time (as in our study) rather than absolute ESV estimate at one point in time (Kreuter et al., 2001; Yi et al., 2017; Zhao et al., 2004), still, we suggest that how to adjust the global value coefficients such that it accurately reflect local ecosystem conditions of Nigeria should be discussed in further studies in order for this type of analysis that we conducted to become more valuable for formulation of land-use policies. Modifications of these global value coefficients could be made according to expert opinion surveys or based on statistical models of spatial and other dependencies (Song and Deng, 2017). Besides, future studies could focus on the generation of BTM-based value coefficients for Nigeria through the transfer of values from a meta-analyses of valuation studies in Africa countries similar to Nigeria in terms of their ecological, cultural, social and economic characteristics while adjusting the values to reflect differences in local income (DEFRA, 2007; Pascual et al., 2010; Mendoza-González et al., 2012) as this could ensure the application of a more robust BTM-based value coefficients in Nigeria. More appropriately is the conduct of original valuation studies supported through funding commitments by governments to obtain location-specific values for ecosystem services in Nigeria.

Our approach of employing land-cover datasets as a proxy of measurement facilitated the estimation process of ecosystem services and their changes in relation to land-use as confirmed in previous studies (Kreuter et al., 2001; Wang et al., 2006; Li et al., 2010; Kindu et al., 2016). However, some limitations of the land-cover data sets exist. The high resolution dataset of 30 m resolution that we have applied was only available for the years 2000 and 2010, which seems to be quite old considering Nigeria's increasing performance in economic activity and the large growing population (World Bank, 2016). Also, the land-cover datasets do not have a detailed classification and the biomes used as proxies for the LULC categories are not perfect matches in every case as inherent in previous studies (e.g. Kreuter et al., 2001; Wang et al., 2006; Zhao et al., 2004; Hu et al., 2008). For example, urban areas were not distinguished from the rural settlements in the datasets, thus, we used built-up areas (which include both rural and urban areas) as proxy for urban and estimated the ESV of the total built-up areas in Nigeria rather than based on the areas of urban. In addition, cropland was used as a proxy for cultivated land but GlobeLand30 defines its cultivated land to include some pastures (Table 1), which implies that this land class in some areas may not only contain cropland but also cultivated pastures and may present some over over-estimation of the ESV of this LULC type. Further, the overall accuracy of Globeland30 land-cover product does not meet the minimum of 85% specified by Anderson et al. (1976), which may have influence on the accuracy of land-change analysis through misclassification of the LULC types (Arowolo and Deng, 2018) and consequently the estimation of ESV. Thus, to overcome these limitations, a more detailed LULC classification and most preferably generation of national land-cover datasets with high resolution and required accuracy of a minimum of 85% are needed because the quality of ecosystem services valuation on one part depends on the accuracy of LULC classification (Konarska et al., 2002).

5. Conclusions

This study provides a much-needed first national assessment of the impact of the dynamics of LULC on ecosystem services provision in Nigeria. Our results revealed that substantial land changes occurred in Nigeria during the period of 2000 to 2010. Most notable is the large increase in cultivated land mainly to the detriment of the forests and savannahs. Largely attributable to the 19.2% increase in cultivated land, our estimate shows that total ESV Nigeria increased by 1.5 billion US$ from 2000 to 2010 (an increase of 0.23%). It is interesting to note that it could be thought that the ESV that is lost due to land-use change are over-compensated by the gained economic value of cultivated land and land-use changes may seem economically profitable. However, loss of services largely provided by the natural ecosystems may result in long-term degradation of environmental quality and decline in services such as climate regulation and water regulation may result in large economic losses through the impact of climate change and flooding. When this occurs, then the apparent gains from cultivated land expansion are also lost. Therefore, recognizing the environmental importance of these natural ecosystems, sustainable development policies in Nigeria must address the impact of the loss of the natural ecosystem due to drastic cultivated land increase, a country highly vulnerable to climate change and incessantly impacted by natural disasters such as flooding. Measures aimed at increasing agricultural productivity such as secure land ownership to motivate farmers to cultivate efficiently, technological advancement, improved farming technology etc., remain one of the best ways to reducing the need to more land-uses for cultivation while minimizing pressure on the increasingly scarce land resource and conserving the natural ecosystems in Nigeria.

Acknowledgments

We gratefully acknowledge the financial support for this research from the Strategic Priority Research Program of the Chinese Academy of Sciences (Grant No. XDA20010302), the National Key Research and Development Program of China (Grant No. 2016YFA0602500), the National Natural Science Foundation of International (Regional) Cooperation and Exchange Programs (Grant No. 71561137002), the National Natural Science Foundation of China (Grant No.71533004, 41171568) and the China Scholarship Council (CSC, File No. 2015GXYG55). The funding agencies had no role in study design, in the collection, analysis and interpretation of data, in the writing of the report, and in the decision to submit the article for publication.

Appendix A. Electronic supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.scitotenv.2018.04.277.

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